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Power Systems Balancing with High Penetration Renewables: The Potential of Demand Response in Hawai'i

Collaborators: Karl Critz (MIT), Sarah Busche (NREL), Stephen Connors (PI, MIT)

The Renewable Energy Challenge

The State of Hawai'i is pursuing a clean energy mix that may involve up to 500 MW of intermittent wind power by 2030. Islands like Hawai'i can achieve significant penetration of intermittent renewable energy sources well before mainland grids, and must confront operational constraints such as high-demand reserve requirements and low-demand wind energy curtailment. The team investigated the ability of Demand Response (DR) to improve renewable integration, as well as DR program design considerations necessary for DR to reliably balance wind and thermal generation. Techniques evaluated for Hawai'i can inform renewable integration efforts for other regions.

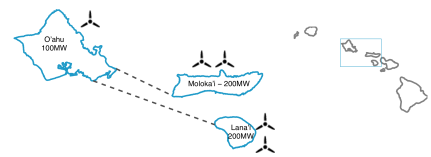

Figure 1. An O'ahu Wind Integration and Transmission Study 500MW wind configuration poses integration challenges.

The Potential Value of Demand Response

The study simulated stochastic rolling unit commitment (via the WILMAR model) on the 2030 grid for a full year of hourly data with wind forecast uncertainty. Twelve DR options looked at program size and operational aspects including the cost of calling DR. Results were evaluated by system operating cost, wind energy contribution, reliability reserve, and customer impact (see table 1 for results). An analysis of utility-run direct load control programs was conducted to reveal best practices in operation, participation, and participant acquisition.

The model output demonstrated that Demand Response enabled the grid's thermal generators to run **more efficiently**. In all scenarios, baseload and peaking generators spent less time at inefficient minimum load levels (circled in figure 2) because fast-acting DR provided reserve capacity.

Demand Response also **enhanced reliability**. Even small quantities of DR (dotted line in figure 3) reduced the number of hours without adequate reserve and the severity of the deficit. Larger DR program sizes achieved desired operating reserves.

Demand Response also reduced **wind energy** shedding on low-demand, high-wind nights (magenta area in figure 4). With DR providing negative regulation, thermal units were able to run closer to their minimum levels. Bidirectional DR was able to add load when needed.

An analysis of past utility Direct Load Control programs showed that program design considerations impose constraints beyond those modeled here. Most DLC programs limited the frequency and duration of customer curtailments, sometimes offering multiple rebate levels for varying amounts of curtailment. This assures participants that impact on their energy use will be minimal. While the simulations assumed the availability of significant amounts of DR, historical participation has often been limited by low incentives, hardware incompatibility, poor program promotion and information about actual customer impacts and benefits.

Performance Metric (2030)	Unit	No DR	With DR
Operational cost	$/MWh, mean	104	92
Wind energy potential	% of demand	25	26
Reliability reserve deficit	days/year	31	0
Demand response calls	days/year	0	18

Table 1. Improvement with Demand Response

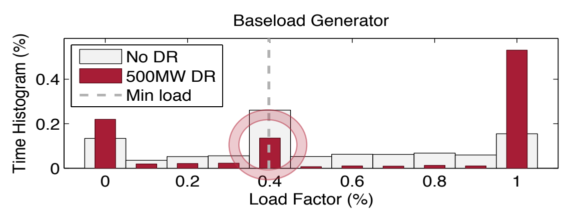

Figure 2. Improvement in thermal efficiency

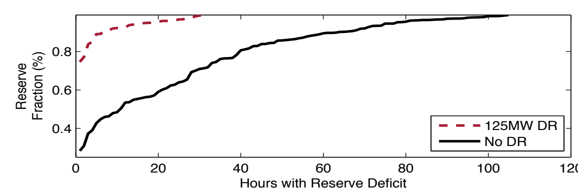

Figure 3. Improvement in reliability reserve

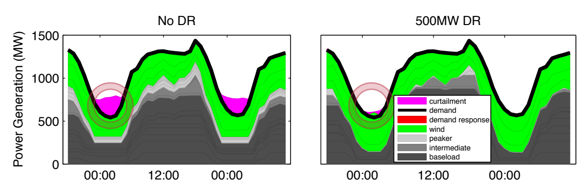

Figure 4. Improvement in wind harvesting

Next Steps

Disseminate the results of this study. Refine key insights and technical recommendations, especially as they relate to real-world experiences. Engage with island grid operators, such as The Hawaiian Electric Co., on what it will take to make DR and similar approaches robust solutions for grids with increasingly variable supplies and demands.

Conclusions

Demand Response represents an opportunity for additional low-cost, infrequently dispatched operating reserves. DR enhances system operation by enabling thermal generators to operate more efficiently. DR program design should favor **broad participation, fast response, and bidirectional (up/down) regulation**. High marginal incentive payments and infrequent dispatch improve system operation with minimal consumer impact. The increased flexibility of DR should help Hawai'i respond to forecast uncertainties and meet its renewable and energy security goals.

Joint Institute for Strategic Energy Analysis
1617 Cole Blvd.
Golden, CO 80401-3393

Contacts
Stephen Connors connorsr@mit.edu
Sarah Busche Sarah.Busche@nrel.gov
Karl Critz dmark@mit.edu

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